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Fish mortalities result from a variety of causes, some of natural origin and some man-induced. The study discusses these natural fish kills are those that are caused by phenomena such as acute temperature change, storms, ice and snow cover, decomposition of natural organic materials, salinity changes, spawning mortalities, and bacterial, parasitic and viral epidemics. Man-induced fish kills may be attributed to municipal or industrial wastes, agricultural activities and water manipulations.

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INVESTIGATING FISH MORTALITIES

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INVESTIGATING FISH

DIVISION OF TECHNICAL SUPPORT
FEDERAL WATER POLLUTION CONTROL
ADMINISTRATION
U.S. DEPARTMENT OF THE INTERIOR

CWT-5, 1970

MORTALITIES

INTRODUCTION

Fish mortalities result from a variety of causes, some of natural origin and some man-induced. Natural fish kills are those that are caused by phenomena such as acute temperature change, storms, ice and snow cover, decomposition of natural organic materials, salinity changes, spawning mortalities, and bacterial, parasitic and viral epidemics. Man-induced fish kills may be attributed to municipal or industrial wastes, agricultural activities and water manipulations.

FISH KILL CAUSES

The Ohio River Valley Water Sanitation Commission published "Procedures for the Investigation of Fish-Kills" in 1956* and listed a number of fish mortality causes. Among those listed were winter kills in northern areas

*Ohio River Valley Water Sanitation Commission. 1956. Procedures for Investigation of Fish-Kills, A Guide for Field Reconnaissance and Data Collection, 24 pp.

where ice cover on shallow lakes and ponds became topped with snow, and the resulting opaqueness stopped photosynthesis. Algae and vascular plants died because of insufficient light, and in their decomposition the oxygen was removed from the water.

Oxygen depletion and extreme pH variation can be caused also by algae or higher-plant respiration and decay during the summer months in very warm weather. Kills resulting from such cases are often associated with a series of cloudy days following a period of hot dry sunny days. Occasionally fish may be killed by toxins released from certain species of living or decaying algae. Algal growth is often stimulated by increased fertility from organic pollution.

Temperature changes, either natural or the result of a heated water discharge, will often result in fish kills. Long periods of very warm dry weather may raise water temperatures above lethal levels for particular species. A wind induced seiche may be hazardous to certain temperature-sensitive deep-lake cold water fish or fish of shallow coastal waters.

Disease, a dense infestation of parasites, or natural death of weakened fish at spawning time must always be suspected as contributory factors in fish mortalities.

Explosions, abrupt water level fluctuations, hurricanes, extreme turbidity or siltation, discharges of toxic chemicals, and certain insecticides, algicides, and herbicides may each cause fish kills.

Recent investigations in Tennessee have shown that the leaking of small amounts of very toxic chemicals from spent pesticide-containing barrels used as floats for piers and diving rafts in lakes and reservoirs can produce extensive fish kills.

Fish die of old age, but the numbers so afflicted at any one time are usually small.

SPEED OF INVESTIGATIVE RESPONSE

Speed is all-important in the initial phases of any fish kill investigation; dead fish disintegrate rapidly in hot weather, and the cause of death may disappear or become unidentifiable within minutes. Early arrival at the scene, after a fish kill begins, usually determines the success of the investigator's evaluation of the problem. The initial investigation can be greatly expedited by enlisting and instructing qualified persons who will report immediately the time and place of observed kills, the general kinds of organisms affected, an estimate of the dead fish total and any unusual phenomena associated with the kill.

PREPARING FOR THE INVESTIGATION

There is always the possibility of legal liability associated with a fish kill. Thus, the investigator's report may be subjected to the scrutiny of judge or jury. Both planning and conduct of the investigation must be done with great care. A carefully developed routine field procedure should be available for immediate activation whenever an emergency fish kill is reported.

When a kill report is received, consult maps of the area to be investigated. Locate the kill area on the maps. Determine the best access points. Locate known industries, municipalities, or other potential sources of pollution. Estimate the area to be inspected and whether air, water, or land inspection is needed. Determine the size of boat and motors, if needed. Ascertain if there is a history of fish kills for the area. The Federal Water Pollution Control Administration's annual publication on Pollution Caused Fish Kills may be helpful here.

Equipment for all investigations should include: thermometer, dissolved oxygen test kit or calibrated electronic probe, conductivity meter, pH meter, general chemistry kit, dip

net, Petersen dredge, square foot stream bottom sampler, and appropriate standard sieves, buckets, boats, waders, etc. A long-handled common garden rake is a useful tool to collect higher aquatic plants or to remove specimens from debris that may be snake- or wasp-infested in certain parts of the country. Always include an ice chest, chemical sample bottles, appropriate specimen containers and preservative. The investigating team should include at least one person experienced in investigating fish kills and who is competent to report the technical aspects of the investigation.

Laboratories that will analyze samples should be alerted, and given an estimate of the number and kinds of samples to be submitted, types of analyses required, how samples will be shipped and date of arrival. The laboratories should also be told the date their analytical results are needed and where and to whom the results should be sent.

THE FIELD INVESTIGATION

As a first step, the investigator should contact local persons who first observed and reported the kill. Whenever possible, these persons should be retained to guide the investigating team. The kill area should also be reconnoitered to determine its relative extent as a basis for decisions that will be involved in the subsequent investigation.

Preliminary Information

The time when the fish kill began and when it ended should be carefully determined from local observers or by the investigator himself. The fish kill area should be carefully ascertained and defined by reference to legal descriptions of adjacent lands or political subdivision. In streams, and often in lakes, fish are washed or blown rapidly away from the kill location; the cause of the kill may be carried

downstream with the current along with floating fish.

The number of fish killed should be estimated as accurately as possible. Estimates are often difficult to make because all dead fish are not observable, and in large numbers, counts are impractical. For large rivers and lakes a measured distance of shoreline may be traversed by boat and the number and kinds of dead or dying fish counted. Estimates can be made by projecting representative counts to the total kill area. For smaller streams, the banks may be walked and counts made on the observed numbers of dead fish by species.

Dead fish should be identified by common and scientific name. The kinds of fish involved, and the relative numbers of each are needed facts.

An appraisal should be made of the size-range of each species killed, and with it observations on the predominance of particular size groups, if distribution appears to be other than random.

Similar observations should be made for any other dead wildlife or animals associated with the kill area, including invertebrates.

It is desirable to record the names of witnesses to the kill, together with a detailed report of their observations and a signed statement if possible. This information will be useful in later legal actions, should these occur.

Physical Observations

Water temperature fluctuation is a possible direct or contributing cause to fish mortalities. Temperatures should be recorded from near the water's surface over a series of hours, especially during the hottest period of the day. When artificially warmed waters are contributing to the temperature problem, a recording thermometer is useful to obtain valuable data over the 24-hour day. When temperature has been suspected to have caused a fish kill, tem-

perature measurements at various depths should be recorded.

Streamflow should be observed, noting especially whether it is constant or intermittent, stagnant or rapidly moving, and the tidal stage. When possible, a stream gage reading should be made.

Weather conditions prevailing at the time of the investigation, at the reported time of the kill, and for two to three days prior thereto should be noted. These data can usually be collected from weather bureau sources. Of particular importance are air temperature, precipitation, and wind direction and speed.

Observations by an experienced investigator are invaluable to defining the cause of a given kill. Perhaps no single factor is so important. Particularly noteworthy are the general appearance of the water, its color, clarity, and whether sparkling or dull and lifeless. The presence of oil, excessive algae, unusual biotic growths such as sewage fungus (*Sphaerotilus*), excessive amounts of higher aquatic plants, and the color and appearance of rocks, sticks or debris within the water are important considerations. Notes on the actions of the fish prior to death are important, as well as observed actions of other organisms, such as crayfish or other benthos. Often much can be learned regarding the severity of the kill to the aquatic environment by lifting a rock from the stream bed or a piece of debris from the water and noting the types of organisms that remain alive.

A map of the fish kill area, accurately locating sampling points, waste outfalls, and other items of importance should be drawn and included in the report.

Lastly photographs, preferably both color and black-and-white, should be taken to record and substantiate the physical conditions observed at the kill site. Black-and-white prints are more suitable for inclusion in the report. It is important to have some identifiable object in the picture to serve as a point of reference and

as a scale to the area encompassed by the photo. The use of a polaroid filter will reduce the glare of reflected light from the water's surface.

Chemical Data

Chemical and biological data should be collected at various stations throughout the kill area, in an upstream unaffected area, and in a downstream area where the water environment has recovered from the pollution. Station locations should be sufficient to trace the extent of the pollution's effects. Samples for chemical analyses should be collected from all waste discharges or other significant pollutional sources.

Locating the sampling stations is a matter for the judgment of an experienced observer. In a lake, stations may be located on transect lines originating from an identifiable point on shore or major pollutional source. Streams less than 200 feet wide may require only one station per transect. Wider streams should have two or more stations per transect, each representative of that portion of the stream in which it is located. Rivers more than 200 feet wide may require extensive cross sectional sampling to show the precise effects of agricultural or other types of mass runoff.

On streams that are five feet or less in depth, one mid-depth sample per sampling station should suffice. In streams of greater depths, samples from the 0.2 and 0.8 strata will usually provide adequate information. In lakes it is often necessary to sample a station vertically at 10-feet or closer intervals, depending on thermal and chemical stratification, in addition to taking surface and near-bottom samples.

Dissolved oxygen should be observed periodically during a 24-hour period in every water where oxygen depletion is a possibility. When diurnal fluctuations of appreciable magnitude are suspected, observations should be made at one-hour or other closely spaced intervals

throughout the 24-hour day. An electronic dissolved oxygen probe and portable recorder may facilitate these measurements.

Specific conductance, pH, and methyl orange alkalinity should be measured.

Water samples for chemical analyses should be collected in chemically cleaned bottles and analyzed for suspected toxic substances. A 1-liter sample is minimal, and 10 such samples from the kill area may prove valuable.

To preserve water, mud, and biologic samples for pesticides analyses the freezing of all wet samples is recommended. When freezing cannot be done, thoroughly cleaned glass containers must be used. The glass bottles should have a screw type cap lined with teflon. Bottles are rinsed successively with chromic acid cleaning solution, running tap water, distilled water, and finally several times with redistilled solvent (e.g., acetone, hexane, petroleum ether, or chloroform). Caps and liners are washed with detergent, rinsed with tap water, distilled water and solvent.

Waterproof tags should be attached to all samples, stating place, date and time of collection, type or sample, condition of the specimen when collected (e.g., affected but not dead), and the name and agency of the sample collector

The size of silt or sludge samples will vary from a quart to a gallon; these are collected preferably in quart glass jars.

Dry samples require no preservative; neither do wet silt or sludges, when samples are dried rapidly. When not dried rapidly, these samples may be preserved with 10 percent formalin. Preservation method should be indicated on the label.

Biological Data

In every investigation of fish or wildlife kills, the investigator should collect dying or recently dead organisms. Moribund, but still living, fish

are best. Several specimens, totaling at least 10 pounds and including 10 fish, of a given species and size affected should be collected. These are placed separately in plastic bags, labeled, quickfrozen immediately with dry ice, and shipped frozen to the laboratory. A similar poundage and number of live specimens of the affected species should be obtained from outside the kill area, but within the same water body, to serve as controls. It is important that these be frozen at the same time as the samples of dying specimens from the affected area. These also are individually placed in plastic bags and labeled. The entire collection can be shipped in polyurethane chests containing dry ice.

Similar samples of five fish each should be preserved for histological examination. Small fish are preferable for this purpose. Because there is no "universal fixative," it is suggested that 10 percent formalin be used. For histological purposes 10 percent buffered formalin is preferred, however, when some of the tissues are to be used for chemical analyses. These chemical analyses desired determine whether unbuffered or buffered formalin is used.

The fixing fluid volume should be approximately 10 times the bulk of the fish tissue. Absorbent cotton or small pieces of tissue paper should be placed at bottom and top inside the specimen jar to keep the specimen from pressing against the jar. Samples should be placed in the fixative as quickly as feasible, to minimize post-mortem changes.

An abdominal incision in fish of five-inch length or less before placing in formalin will preserve the internal organs. The operculum should be clipped to expose the gills for more rapid fixation. It is quite simple to expose the brain by making a cut just posterior and dorsal to the eyes. Formalin may be injected into the brain case with a hypodermic needle; however, this must be done very slowly to avoid excessive pressure that may damage brain tissue.

With specimens over five inches in length, it is desirable to remove the internal organs and fix them separately. If this is not feasible, then the fish should be preserved in the manner described for smaller specimens and at the earliest convenient time the internal organs removed and preserved. Membranes, such as those overlying the kidney, should be carefully removed to allow the fixative to penetrate the tissue.

Do not crush, tear or squeeze tissue when removing it from the carcass. A razor blade or sharp scalpel is preferred to scissors in dissecting and removing the tissue for there is less chance of mechanical damage.

Tissues may remain in the preservative until further treatment in the laboratory. Preservative solutions may be made as follows:

10% Formalin Solution

37–40% Formaldehyde	100 cc
Tap water	900 cc

Buffered Formalin Solution

37–40% formaldehyde	100 cc
Distilled water	900 cc
Sodium phosphate monobasic	4 gm
Sodium phosphate dibasic	6.5 gm

Home-canning type jars with new lids generally work well as specimen containers, but they should be well protected from breakage by packing in excelsior or shredded paper. Absorbent material such as paper toweling should also be provided in the event of leakage. A better preparation for shipping consists of first placing the fish in the proper fixative as described for a day or two, then sealing the preserved fish in a plastic bag containing very small volume of fixative. A second plastic bag should then be placed over the first and also sealed. This provides a very durable package of minimal weight. When shipped by air, packing

should provide room for gas expansion which occurs in high altitude flights. One-half air space volume in the plastic bags will suffice.

When disease is suspected, five moribund fish of each involved species should be placed on wet ice and delivered to a fish disease laboratory within 24 hours to obtain satisfactory information on some fish diseases.

A properly completed "Fish Mortality Information" sheet (Appendix A) is invaluable to the analyst.

Accurate recording of symptoms when collecting specimens is of great importance in diagnosing the causative agent or agents (Appendix B). Conditions such as general appearance, sites of hemorrhage, body color, organ color, etc., must be recorded immediately upon capture.

Blood samples should be collected from dying or recently dead fish. This involves drying the exterior of the fish with paper towels, wrapping a paper towel around the fish in the anal region, and cutting off the caudal peduncle (tail) with sharp scissors. The fish is held in a vertical position, tail down, with the blood dropping into a 10–15 cc vial until 5 cc of blood is collected. If blood clotting reduces the flow, a second shearing may again free the flow. Composite samples from several fish of the same species may be necessary to obtain 5 cc of blood. Five vials containing 5 cc each of blood for each important species are preferred. The vial stopper or cap is covered with aluminum foil, the vial is closed, and the sample is frozen immediately, making certain that the sample does not touch the foil. A code number is given to the blood sample so that it can be matched with the carcass, which is retained and frozen separately in a plastic bag.

Taking blood from a bird or mammal is more difficult, and can best be done in the laboratory from the frozen carcass.

Bio-assays are useful to determine whether the water at the time of the investigation is still

toxic, and therefore whether the collected water samples contain the toxic substance, and to determine the dilution that will kill fish. The bio-assays can be conducted with unaffected fish from the water being investigated, when practical, or with purchased guppies or goldfish, and water from the kill area. Bio-assays should be conducted in accordance with procedures delineated in the current edition of "Standard Methods for the Examination of Water and Wastewater."

Caged fish, or invertebrates, in wire baskets, placed at selected points upstream and downstream from a suspected source of continuing toxicity will assist in determining the limits of the toxic area and identifying the source of the toxicity.

It is important to make collections of algae when they are present in quantities sufficient to be a potential factor in the kill. Careful observations on the extent and density of rooted aquatic plants should also be made.

In collecting attached or planktonic algae for pesticidal analysis, collect 10 cc of concentrated material in a 20 cc glass vial. Attach tag giving basic collection identification and indicate volume of water from which the sample was collected and the method of concentration. Cover top with aluminum foil, cap, and ship frozen. Dilute fresh algal cell or an algal suspension in the affected water may be injected into laboratory mice to determine algal toxicity. Such samples should be returned rapidly to the laboratory in a fresh and chilled state.

Following completion of the more urgent aspects of the fish kill investigation, sampling of benthic organisms in the accepted manner for biologic investigation of water pollution will aid in defining the extent and cause of the fish kill. Because these organisms are restricted in mobility to a habitat area, harmful materials released to the environment will affect this population. The relative state of pollution in a stream reach can be dramatically observed in

the benthic animal population. It should be noted that, under certain conditions, a particular water quality may affect fish more severely than benthos, or vice versa.

Sample Collection Summary

1. Ten 1-liter water samples from kill area for chemical analyses. Other 1-L samples from control and other stations.
2. Ten pounds including 10 individuals of dying fish of each important species frozen with dry ice. An equivalent amount and number of control fish.
3. Five small fish of each important species preserved in formalin.
4. Five dying fish of each significant species placed on wet ice and delivered to fish disease laboratory within 24 hours.
5. Five vials containing 5 cc each of blood from each important species.
6. Ten gallons of water for bio-assay.
7. One quart to 1 gallon of sludge or sediment.
8. Ten cc of concentrated algae, frozen.
9. Ten cc of concentrated algae, chilled.
10. Benthos samples.

THE INVESTIGATION'S EXTENT

To what extent should one investigate a given fish mortality? Part of the answer obviously lies in the extent of the kill, the numbers and kinds of fish involved, and the resources available to investigate. Following a decision to investigate, the investigation should continue until a cause is determined, or until all known potential causes have been eliminated as being implicated in the kill.

The investigation may be completed with the taking of water temperature, dissolved oxygen or pH, and the determining of the cause of the deleterious change in water quality. On the other hand, the investigation may continue

through many sophisticated analyses, each contributing something, either positive or negative, to the sum total of knowledge. Each possibility should be systematically eliminated. Disease, parasites, and cellular tissue changes should be considered as contributory to death until eliminated.

REPORTING THE RESULTS

The report should be such that it can be introduced as evidence into court and withstand critical cross-examination. Samples collected in the field and transported to a central laboratory for examination, should be sealed and so identified by the sender that the chain of evidence remains intact. Each sample, as received in the laboratory, should be logged in and thereafter the date and exact time for each step in the analysis recorded by the responsible technician. The log should be continuous, and account for all time that the sample is in the laboratory until analysis is completed. When not in use, samples should be in a locked room.

The report should be a systematic recording of organized thought to convey the fact findings of the investigation accurately, completely, and understandably to the reader. Good technical writing is clear and concise, omitting needless words. When a word adds nothing identifiable to a sentence, it should be left out. The who, what, why, when, where, and how questions must be answered at every opportunity. Noncommittal language should be avoided. Calculations should be checked and rechecked—tabular data against bench cards, graphs against tabular data; citations should be attributed to proper sources in accurately arranged bibliographies.

These are the essential elements of a fish kill investigator's report:

(1) An Introduction that describes briefly where the kill occurred, when and by whom it was reported, who made the

investigation and when, and the authority for the investigation;

(2) A Summary description of the findings brought out by the investigation, including extent of the kill, and the numbers and species of fish involved;

(3) Conclusions that detail the cause of the kill;

(4) Recommendations that specify how similar kills may be prevented in the future;

(5) A Description of Study Area section that includes an area location map showing the extent of the kill, principal population centers, major waste sources, and sampling stations;

(6) A Fish Mortality Discussion section that details in logical manner the steps taken in the investigation and the knowledge gained from each;

(7) A Water Uses section detailing the uses and value of the affected waterway;

(8) A Damages section that assigns a monetary value, when practical, to the fish kill;

(9) An Appendix that includes all tabular data; describes the manipulations used to estimate the numbers of fish killed and how their value was determined; and that further describes any nonstandard biological and chemical analytical procedures used.

All field notes, laboratory notes and data forms must be maintained in the agency files until there is assurance that they will not be needed further in court actions or elsewhere.

Appendix A

FISH MORTALITY INFORMATION*

1. WATER CONDITIONS

Clear ☐ Turbid ☐ Muddy ☐
Colored ☐ Indicate color _____
Temp. _____°F pH _____ O₂mg/l _____

2. FISH		
Species involved	Estimated Numbers	Date of reported kill: Date of Investigation: Location of kill:

3. GENERAL APPEARANCE

Normal ☐ Nervous and scary ☐
Sluggish ☐ Floating listlessly ☐
Flashing ☐ Swimming upside down or on the side ☐
Spiraling or corkscrewing ☐
Making spasmodic movements ☐
Sinking to the bottom ☐
Rubbing against the bottom ☐
Other:

4. ARRANGEMENT IN WATER

Normal Distribution ☐ Schooling ☐ Near surface ☐
Gasping for air ☐ Crowding water inlet ☐
Floating towards outlet ☐ Distribution at even distance, one fish from another, and facing water current ☐

5. BODY SURFACE

Normal ☐ /Bluish film: in patches ☐ or all over ☐
/Grayish-white: patches ☐ or tufts ☐
Swollen areas as furuncles ☐ Deep open lesions with pus and blood ☐ /Shallow red ulcers: small ☐ large ☐
/Necrotic areas: separate ☐ confluent ☐
gray ☐ lt. brown ☐ on head ☐ all over ☐
lips and head especially ☐ /Granulations: glass bead-like ☐ pearl-like ☐ on fins ☐ on body ☐ variable in size ☐ /Pinpoint pimples ☐ Cysts ☐
/Pinpoint spots: white ☐ or black ☐ /Parasites:

*Modified from Bureau of Sport Fisheries and Wildlife form 3-148 (Rev. Mar. 1965)

very small, barely visible, soft ☐ or longer, hard ☐ (often with swallowtail appearance) /Fish abnormally dark: entire body ☐ certain body areas ☐ Indicate where _____

Growth ☐ Irregular ☐ proliferating ☐ on surface ☐ or protruding from: vent ☐ nostrils ☐ mouth ☐ Warts ☐ gills ☐

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6. FINS

Normal ☐ Swollen ☐ Necrotic ☐ Frayed ☐ Bluish-white ☐ Twisted ☐ Eroded ☐ /Spots present: white ☐ black ☐ /Blood-shot ☐ Parasite present ☐

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7. CAUDAL PEDUNCLE

Slightly swollen ☐ Very swollen ☐ Necrotic ☐ Inflamed ☐ Bluish-white ☐ Fungus-like tufts present ☐

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8. GILLS

Covers open more than normally ☐ Swollen ☐ Covered with mucus, food and dirt particles ☐ Patches: white ☐ brown ☐ gray ☐

(IF EXAMINED UNDER MICROSCOPE)

Filaments and Lamellae: swollen ☐ fused ☐ club-shaped ☐ ballooned ☐ Cottony tufts present ☐ Small grayish-white objects: on filaments ☐ on lamellae ☐ between filaments ☐ between lamellae ☐ Color of gills: deep red ☐ pale red ☐ pale pink ☐ hemorrhagic ☐

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9. MUSCULATURE

Sores ☐ or Furuncles ☐ filled with red pus Small red spots ☐ Well defined sores ☐ or cysts ☐ filled with creamy ☐ or cheesy ☐ contents Hard cysts like sand grains: small ☐ large ☐ black ☐ or yellow ☐

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10. EYES

Normal ☐ Opaque ☐ White: lens ☐ or center ☐ Tiny spots in lens ☐ Red spots in cornea ☐ Popeye ☐ One eye missing ☐ Both eyes missing ☐ If a needle is inserted in the eye socket and the eye is pressed while fish head is under water, gas bubbles ☐ or opaque fluid ☐ escapes.

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11. BODY CAVITY

Appears normal ☐ Excessive fluid present ☐ /Fluid: Colorless ☐ Opaque ☐ Bloody ☐ /Present in lining: Spots ☐ or Hemorrhages ☐
/Worms: Tape-like ☐ or Round ☐ /Small Cysts ☐

12. INTESTINAL TRACT

Normal ☐ Empty ☐ Filled with food ☐ /Filled with mucus: Colorless ☐ Yellow ☐ Reddish ☐
Hind gut bloody ☐ Blood in vent ☐ Stomach opened ☐
Roundworms present ☐ Flatworms present ☐

13. LIVER

Normal ☐ Red ☐ Yellow ☐ Brown ☐ Pale ☐
Color of coffee with cream ☐ Marbled ☐ Spotty ☐ /Cysts: Small ☐ or Large ☐
/Gall Bladder Bile: Greenish-yellow ☐ or Bluish-Black ☐
Watery Clear ☐

14. SPLEEN

Red ☐ Black-red ☐ Pale ☐ Spotty ☐ Shriveled ☐ Swollen ☐ Lumpy ☐ Grossly Enlarged ☐

15. PYLORIC CAECA

Normal ☐ Fused together ☐ Swollen ☐ Worms Inside ☐ Bloodshot ☐

16. KIDNEY

Normal ☐ /Pinpoint Spots: Gray ☐ or White ☐
Gray pustules: How many: Where located:
Small ☐ Large ☐ Creamy consistency ☐ Hard and gritty ☐ Cheesy Consistency ☐

17. TUMORS

Any internal organ: Much enlarged ☐ Irregular in shape ☐

18. OTHER CONDITIONS OR SYMPTOMS NOTED: (Continue on reverse, if necessary)

Name and address of investigator:

Appendix B

Symptoms that have been Related to Cause of Fish Death*

SYMPTOMS	CAUSATIVE AGENTS	REFERENCES
White film on gills, skin, and mouth	Acids, heavy metals; trinitrophenol	Ellis, 1937
Sloughing of gill epithelium	Copper; zinc; lead	Anon., 1961
	Lead	Carpenter, 1930
	Detergents	Schmid and Mann, 1961
	Ammonia	Kuhn and Koecke, 1956
	Quinoline	Shelford, 1917
Gill occlusion	Turbidity	Wallen, 1951
	Ferric hydroxide, precipitated	Stundle, 1955
Bright red gills	Cyanide	Alexander et al., 1935
Dark gills	Phenolic poisoning	Havelka and Effenberger, 1957; Skrapek, 1963
	p-cresol; naphthalene; oxygen deficiency	Alexander et al., 1935
Gill lamellae thickening	Hydrogen sulfide	Wood, 1960
Distended gill covers	Phenol; cresols	Shelford, 1917
	Ammonia	Jones, 1948
	Cyanide	Alexander et al., 1935
Swollen abdomens	Chlorinated hydrocarbon insecticides	Henderson et al., 1959
Blue stomachs	Molybdenum	Easterday and Miller, 1963
Intestinal epithelium destruction	Hexavalent chromium	Fromm and Schiffman, 1958
	Kraft pulp mill wastes	Fujiya, 1961
Liver lesions	DDT, 3 ppm	Mathur, 1962a
	Lindane, 5 ppm; BHC, 10 ppm	Mathur, 1962b
Gall Bladder distension	Kraft mill wastes	Extrom and Farner, 1943

*From Swabey, Y. H., 1966. The Autopsy of Fish Collected in Fish Kills. Research Publication No. 11, The Ontario Water Resources Commission

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